

MARKED UP VERSION OF SPECIFICATION
ILLUMINATING SYSTEM AND METHOD FOR IMPROVING
ASYMMETRIC PROJECTION

5 **CROSS REFERENCE TO RELATED APPLICATION**

This application incorporates by reference Taiwanese application Serial No. 90128276, filed on 11/15/2001.

BACKGROUND OF THE INVENTION

10 [0001]1. Field of the Invention

[0002] The present invention relates to a projection system and, more particularly, to an illuminating system and method for improving asymmetric projection in a projection system.

[0003]2. Description of Related Art

15 [0004] Referring to FIG 1, a projection system 20 in a prior art is a single panel full color system having a light source 21 with a parabolic concave reflector 211 to emit a white light beam 23. After reflected by the parabolic concave reflector 211, the white light beam 23 passes through a converging lens 22 to converge the light beam 23 on a color wheel 24. When rotating around a shaft, the color wheel 24 has a
20 sequence of red, green, and blue filters to intercept the light beam 23 in order, so the light beam 23 shifts into a color light beam 25 as passing through the color wheel 24. Then, the color light beam 25 transmits in order through an integration rod 26, a condenser lens 27, a stop 28, and a relay lens 29 to impinge in a prism 30, and a mirror 31 in the prism 30 reflects the color light beam 25 to a light valve 10, such as
25 Digital Micro-mirror Device (hereinafter referred to as "DMD"). Therefore, the light valve 10 modulates the color light beam 25 to generate an image light and reflects the image light into a projection lens 32 for projecting an image onto a screen (not shown).

30 [0005] The DMD has an array of inclinable mirrors corresponding to an array of pixels constituting the image. When one of inclinable mirrors reflects a light beam to the screen, the inclinable mirrors is referred to as "on-state"; when reflecting a light

beam off the screen, the pixel mirror is referred to as "off-state"; when the pixel mirror parallel the DMD board, that is between the on-state and the off-state, the pixel mirror is referred to as "flat-state".

[0006] FIG. 2 shows a second projection system 40 in a prior art. The difference, between the first projection system 20 and the second projection system 40, is that the light source 41 of the second projection system 40 has an elliptic concave reflector 411. The elliptic concave reflector 411 reflects and converges a light beam, emitted from the light source 41, to a color wheel 44 without passing a converging lens. For the rest, the second projection system 40 is the same as the first projection system 20 and actually is one embodiment of the first projection system 20. To simplify the description, the first projection system 20 was only described as an example in the following specification, but its technologies can be fully suitable for the second projection system 40.

[0007] In the first projection system 20, from the light source 21 to the light valve 10, the light beam passes through any optical element, such as the converging lens 22, the color wheel 24, integration rod 26, the condenser lens 27, the stop 28, and the relay lens 29, having the geometrically symmetric feature. Therefore, as shown in FIG. 3, before obliquely impinging onto the light valve 10, the light beam has a rectangular cross section to form a rectangular-sectional light beam 51 with a feature of an intensely uniform illumination. If any above-mentioned optical elements and their assembly are perfect, the length of a first diagonal L1 will be equal to that of a second diagonal L2 on the rectangular-sectional light beam 51, i.e. the rectangular-sectional light beam 51 has no distortion.

[0008] Referring to FIG. 4, when the rectangular-sectional light beam 51, passing through the prism 30, obliquely impinges onto the light valve 10, a light spot 52 is formed thereon. Consequently, the light spot 52 is distorted due to the inclined incidence, so that the length of the first diagonal L1 isn't equal to that of the second diagonal L2, i.e. $L1 > L2$.

[0009] The above-mentioned prior art has at least two drawbacks as follows: one reduces the uniform brightness of the light spot resulted from the unequal extension of two diagonals; the other causes the brightness loss on circumference of the light spot from the extension of the first diagonal L1 out of the light valve and results in

decreasing the illumination efficiency.

SUMMARY OF THE INVENTION

5 [0010] One objective of the present invention is to provide a method for offsetting two asymmetric diagonals of the distorted light spot. By the use of an [anamorphic] asymmetrically curved surface unit of a projection system, the method will improve the asymmetric light spot resulted from the inclined incidence to achieve a more symmetric light spot.

10 [0011] The other objective of the present invention is to use an [anamorphic] asymmetrically curved surface unit for producing two asymmetric orthogonal axes so that an illuminating system can generate a parabolic-sectional light beam with a smaller F-number. Thus, that can avoid the overlap of light beams between on-state and flat-state to raise the contrast. Furthermore, by amplifying the light spot, the projection system will increase the total illumination efficiency of the optic system.

15 BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. 1 is a schematic view showing a light path of a first projection system in the prior art;

[0013] FIG. 2 is a schematic view showing a light path of a second projection system in the prior art;

20 [0014] FIG. 3 is a schematic cross-sectional view showing a non-distortion rectangular light beam of a first projection system in the prior art before the light beam obliquely impinges onto the light valve;

[0015] FIG. 4 is a schematic view showing a distorted rectangular light spot on the light valve in the prior art;

25 [0016] FIG. 5(A)-5(C) is a schematic view showing an improving procedure by the use of an [anamorphic] asymmetrically curved surface unit;

[0017] FIG. 6(A)-6(B) is a spot diagram respectively showing a brightness distribution of the light spot of the prior art and the present invention on DMD;

30 [0018] FIG. 7(A)-7(B) is a schematic view showing the axial-extended elliptic light spot on the stop;

[0019] FIG. 8 is a schematic view showing the relative positions of the open-state, off-state, and flat state of the light beam on the spot of the projection lens;

[0020] FIG. 9(A)-9(B) is a spot diagram respectively showing the brightness distribution of the screen of the prior art and the present invention.

[0021] FIG. 10 is an experimental data list showing the contrast between the present invention and the prior art.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] Referring to the drawings, the present invention will be described in a following embodiment. For solving a distortion of the prior art, the present invention is to provide an [anamorphic] asymmetrically curved surface unit for offsetting the distortion formed by two asymmetric diagonals of a light spot, so that the asymmetric light spot, resulting from inclined incidence of a projection system, can be improved into a more symmetric light spot.

[0023] Referring to FIG. 1, an embodiment of the invention has the same projection system and light path as the first projection system 20 of the prior art. That is, the embodiment of the invention includes the light source 21 producing a light beam 23 to form a light path. The light beam 23 successively passes through the reflector 211, the converging lens 22, the color wheel 24, integration rod 26, the condenser lens 27, the stop 28, the relay lens 29, prism 30, and the mirror 31. Then, the light beam 23 obliquely impinges to the light valve 10 and finally reflects to the projection lens 32 to project an image onto the screen. The difference, between the embodiment of the invention and the first projection system 20, is that the embodiment of the invention has an asymmetrically curved surface unit placed in the light path between the light source 21 and the light valve 10. In general, the [anamorphic] asymmetrically curved surface unit may be formed on one surface of a lens, reflector, or mirror. Concretely, the [anamorphic] asymmetrically curved surface unit may be formed on any surface of the reflector 211, converging lens 22, condenser lens 27, relay lens 29, or mirror 31 [of the projection system shown in FIG. 1].

[0024] Referring to FIG. 5(A)-5(C), [The anamorphic]the asymmetrically curved surface unit 291 is formed on one surface of the relay lens 29 in this embodiment, for example. [Referring to FIG. 5(A)-5(C),] FIG 5(B) shows the relay lens 29 as a rectangular [anamorphic] and asymmetrically curved lens, [having] which has one normal surface 292 and another convex asymmetrically curved surface unit 291 [surface] with larger curvature at X-axis than Y-axis. FIG. 5(A) shows the

distorted light spot 53 on DMD, in which two diagonals at M and N direction is asymmetric each other, and the length of the N-direction diagonal is longer than that of the M-direction diagonal. When using the [anamorphic lens replaces] relay lens 29 with the asymmetrically curved surface unit 291, the X-axis of the [anamorphic] asymmetrically curved surface unit 291 [lens] is in the N-direction of the distorted light spot, and the Y-axis is in the M- direction. Therefore, by means of the different amplifying rates due to the different curvature of the X-axis and the Y-axis, the length of the N-direction diagonal can be shortened to improve the asymmetric light spot on DMD for achieving a more symmetric light spot 54, shown in FIG. 5(C). In the same principle, by the use of the [anamorphic] asymmetrically curved surface unit 291 with the different curvature, the light spot 54 can appropriately be symmetrized or produced a predetermined distortion.

[0025] Referring to FIG. 6, FIG. 6(A) shows a DMD spot diagram of the prior art without an [anamorphic] asymmetrically curved surface unit. Due to the inclined incidence, the light spot of the prior art generates a distortion and appears a diagonal extension from the down-left to up-right corner. That is, the length of the first diagonal L1 is longer than that of the second diagonal L2, shown in FIG. 4. On the contrary, FIG. 6(B) shows a DMD spot diagram of the present invention with an [anamorphic] asymmetrically curved surface unit. By using an [anamorphic] asymmetrically curved surface unit to offset the distortion resulting from inclined incidence, a more symmetric light spot can be achieved. In contrast with the asymmetric light spot, the extension on the diagonal of the DMD light spot, shown in FIG. 6(B), have been improved obviously.

[0026] Furthermore, because the light beam on DMD can only be reflected to the screen through the rear-end projection lens, an available rectangular region need to be defined for matching the DMD within the light spot shown in FIG 6(A) and 6(B). Owing to the producing tolerance, the available rectangular region is slightly larger than the DMD and has the same ratio of length and width as that of the DMD in order to make sure that the light beam can illuminate all DMD. Therefore, the illuminating loss area, between the peripheries of the available rectangular and the asymmetric DMD light spot in the prior art, is larger than that of the present invention, so the total light collection efficiency of the prior art is less than that of the present invention.

[0027] Referring to FIG. 7(A) and 7(B), FIG. 7(A) shows that the light spot on the stop of projection lens 32 is a circle spot due to the relay lens 29 without an [anamorphic] asymmetrically curved surface unit in prior art. FIG. 7(B) shows the light spot on the stop of projection lens 32 due to the relay lens 29 with an
5 [anamorphic] asymmetrically curved surface unit. Because the relay lens 29 has the [anamorphic] asymmetrically curved surface with the different curvatures in X-axis and Y-axis to produce different amplifications, the light spot extends different lengths along the X-axis and Y-axis and forms an elliptic spot. Therefore, the Y-axis length of the light spot on the stop of projection lens 32 is elongated clearly, so that the shape of
10 the light spot transforms a circular into an ellipse to increase the total light collection efficiency of projection system. The technology of the present invention will be described in detail as follows.

[0028] FIG. 8 shows the relative positions of the on-state, off-state, and flat state of the light beam at the stop of the projection lens 32. The solid line respectively
15 represents the on-state light beam 61, flat state light beam 62, and off-state light beam 63 of the prior art, and the dotted line respectively represents the on-state light beam 64, flat-state light beam 65, and off-state light beam 66 of the present invention. In theory, the bigger the on-state light beam 61 is, the more light [flex] flux can be allowed to enter into the stop for achieving better brightness. If the on-state light beam
20 61 is enlarged to produce a light spot 611 having the same size as the stop 67, the flat-state light beam 62 and off-state light beam 63 will also be enlarged as light spot 68 and 69 respectively. That causes the some overlaps between light spot 611 and light spot 68 to decrease the projection contrast. Therefore, the on-state light beam 61, flat state light beam 62, and off-state light beam 63 of the prior art are set to be next to
25 each other and have no X-axial overlap between them, so that the maximum light flux can be allowed to pass without the sacrifice of contrast to achieve the best balance.

[0029] The present invention uses an [anamorphic] asymmetrically curved surface unit for producing two asymmetric orthogonal axes to offset the distorted light spot formed by the inclined incidence of the prior art, so as to achieve a more
30 symmetric light spot. Meanwhile, the present invention may also use the feature of two asymmetric orthogonal axes to extend the light spot of the on-state light beam 64, flat-state light beam 65, and off-state light beam 66 along Y-axis. Then, the diaphragm

of the present invention is enlarged (i.e. the F number decreases). The on-state light beam 64, flat state light beam 65, and off-state light beam 66 of the present invention can respectively replace the on-state light beam 61, flat state light beam 62, and off-state light beam 63 of the prior art. Thus, the present invention can make sure that the elliptic light beam with the larger maximum light flux pass without any loss, and avoid the overlaps between the on-state light beam 64, flat -state light beam 65, and off-state light beam 66.

[0030] FIG. 9(A) and FIG. 9(B) respectively show the screen brightness distribution diagrams of the prior art and the present invention when the light beam on the DMD reflects onto the screen through the rear-end projection lens. As a result, the deep color, shown in FIG. 9(B), representing the high brightness distribution region of the present invention is larger than that of the prior art, as shown in FIG. 9(A), in the brightness region and uniformity of the screen diagram. Furthermore, the X-axis and Y-axis brightness distribution of the present invention is also indeed more uniform than that of the prior art in the screen diagram.

[0031] Referring to FIG. 10, the experimental data list shows the contrast between the present invention and the prior art. The experimental datum includes the percentages of DMD efficiency DMD, overfill, the projection output efficiency of on-state, and the projection output efficiency of flat-state. The right columns of the list show the improving rate of the present invention compared with that of the prior art. As to the improving rates of the present invention, the DMD efficiency is 4.6%; the overfill loss is 16.8%; the projection output efficiency of on-state is 2.9%; the projection output efficiency of flat-state is 69.2 %.

[0032] Although the reflective DMD is a example for describing the above preferred embodiments, it can be replaced with a Liquid Crystal On Silicon (LCOS) or a Liquid Crystal Display (LCD) panel.

[0033] The invention has been described using exemplary preferred embodiments. However, it is to be understood that the scope of the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.